METALLODIELECTRIC ARRAYS
FOR PLASMONIC LOCALIZED ENHANCEMENT

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ABSTRACT

Current tactical networks and applications are greatly constrained by the bandwidth limitations of the RF spectrum. The Future Force is demanding simultaneous voice, video and data applications being streamed to the warfighter, creating a critical need for bandwidth. Recent research on the exploitation of plasmonics for sensor technology shows great promise for the development of future sensors and communication systems. The general focus of our research is to develop lightweight, low power, high bandwidth systems that can be used to gather real time data useful for the tactical environment. Surface plasmonics can achieve each of these criterions through simple, low cost designs. Our research will explore the plasmonic coupling phenomena associated with enhanced transmission through subwavelength apertures and its potential for tactical applications.

1. INTRODUCTION

This research encompasses the exploration of manipulating surface plasmons on metal/dielectric interfaces. It has been shown that these interfaces, when corrugated with an array of holes and spaces can not only amplify incident waves but can also focus scattered, divergent waves into a tight beam. Through this periodic array one can achieve greater than 100% transmission through sub-wavelength holes by coupling to the plasmon modes. This phenomenon has long thought to be restricted by the theories of classical diffraction when dealing with sub-wavelength apertures. The transmission results when the plasmon dispersion curve is shifted, via the array, to intersect with the photon dispersion curve.

Surface Plasmon (SP) wave vector k_{X}, $k_X > \omega / c$
x - projection of incident wave vector $\hbar\omega$/c must be increased by $\Delta\mathrm{k}_{\mathrm{X}}$. (1)

$$k_{\mathrm{X}} = \frac{\omega}{c}\sin\theta_0 \pm \Delta\mathrm{k}_{\mathrm{X}} = \frac{\omega}{c}\sqrt{\frac{\varepsilon}{\varepsilon+1}} = k_{sp}$$

where $\Delta\mathrm{k}_{\mathrm{X}} = n \cdot g$, $g = \frac{2\pi}{d}$, d = grating constant.

1.1. Relevance to the Army

This fundamental research effort will aid combat forces in reducing their visibility to opposing forces over a broad electromagnetic spectrum. As such, it will be investigated for the potential use for sensor technology development through an effort at the US Army RDECOM. Results of this research have the potential to develop a sensor system that is not only secure but shows obstacle penetration characteristics useful for underground and barrier-transmitting communications. Vital tactical programs such as the Warfighter Information Network (WIN-T) and the Future Combat System (FCS) may benefit greatly from this technology in terms of their networks carrying mission critical voice, video and data. The

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potential for high bandwidth communication systems exceeding current RF technologies is an ongoing concern for the warfighter. Relevance to optical systems will also be explored for potential applications.

2. METHODOLOGY

The methodology of our studies has focused on dividing the research into respective phases. The initial phase involved the development of the basic theory underlining the plasmonic coupling phenomena. This approach led to a rarely documented understanding of the discussed metallodielectric array and the associated coupling of electromagnetic waves to the surface plasma. For simplicity, a one-dimensional model (see Fig. 1) was developed with boundary conditions to establish the necessary Maxwell's equations. The next stage involved the numerical solutions for these equations through the use of extensive computer computational techniques. Once these iterative calculations were performed, a basis of understanding for the material characteristics was established, allowing for physical fabrications to commence. The following phases of research will begin to develop a more complete picture of the coupling process by including the full dimensional model.

3. EXPERIMENTATION

In parallel with this effort, devices are being fabricated to develop a prototype for demonstration. Since the actual design of the system is based upon the wavelength of incident electromagnetic waves, it is necessary to choose a spectrum that is cost effective in terms of fabrication. With the increase in incident signal wavelength the array dimensions also increase. At optical wavelengths the scale of the device is within nanometers, whereas for THz wavelengths the device dimensions grow to within micrometers and millimeters. The larger device size means a simpler fabrication process that is much cheaper in cost. However, prototyping in the optical region will allow us to duplicate existing studies therefore verifying our techniques. Both optical devices and THz devices are being fabricated at this time. We expect to have the devices ready for testing within the next few months.

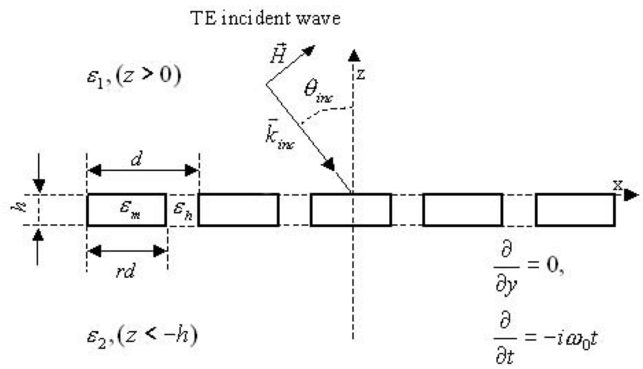

Fig. 1: One-dimensional representation of periodic hole array with associated boundary conditions.

CONCLUSIONS

Exploring plasmonics for sensor technology shows great promise for applications relevant to the warfighter's sensor and communication systems. Our research is looking to establish a foundation of understanding of the plasmonic coupling phenomena through rigorous calculations and experimentation. Our analytical task is to fully maximize plasmonic coupling and to apply its amplification properties to the tactical environment. Sensor research is focused on developing the next generation of lightweight, low power, high bandwidth systems that can be used to gather real time data useful for the tactical environment. Surface plasmonics promises to achieve each of these criterions through simple, low cost designs.

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